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14. ABSTRACT

Accurate seafloor environmental information is crucial to the success of mine hunting operations. Historical environmental data must be supplemented with near real-time information to verify data quality, supplement low resolution information, and in some cases replace inaccurate or perishable data.
With fleet endorsements from OPNAV and COMINEWARCOM, NRL is developing end-to-end techniques to fuse near real-time Through-The-Sensor data with historical information and provide it to MEDAL. AQS-20 environmental data extraction and processing algorithms have been developed and demonstrated. Techniques to fuse dynamic bathymetry and sediment data with historical information are being developed. The active databases, Geophysical Database Variable Grid (GDBV) and Digital Bathymetric Database Variable (DBDBV), have been upgraded to store MCM seafloor information. Tactical Environmental Data Services (TEDServices) has demonstrated its ability to serve environmental data in numerous exercises.
Future efforts include demonstrations of the end-to-end connectivity. TEDServices will be expanded to provide the fused MCM environmental data to MEDAL. The processing software, fusion algorithms, and GDBV will be integrated into NAVOCEANO's Bottom Mapping Workstation. The impact to the mine warfare community will be improved real-time data receipt and reduced MCM timelines.

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Environmental Data Collection, Sensor to Decision Aid

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Abstract

Historical environmental data is very useful; however, it often suffers from incomplete coverage, low data density and perishability. Accurate near real-time environmental data is critical to the success of Mine Warfare operations as was demonstrated in Operation Iraqi Freedom in clearing the approach to the deep water port of Umm Qasr. Prior to the conflict information on seafloor bottom type, expected mine-case burial rates and water depth was inconsistent and dated. MCM ships had to proceed with extreme caution until the bottom types and bathymetry could be determined. Environmental data is needed to determine the right tactics, and minimize the time required to breech an area while maintaining a true sense of mine detection. Dynamic, near real-time, and historical data should be processed and merged onboard, and provided to tactical decision aids as the "best" environment to support Mine Countermeasures.

Overview

NRL is developing techniques that utilize the data stream from tactical systems to also extract ocean environmental measurements for near real-time use.[1] Key components of the effort include fusion of dynamic with historical data to refresh the environmental picture, and delivery of the information to tactical decision aids. This paper discusses an End-To-End Through-The-Sensor (TTS) environmental data collection effort using the AQS-20 mine hunting sensor. End-To-End includes sensor data collection, processing, fusion, storage, distribution and use in tactical decision aids.

Introduction

Environmental data can be extracted from the AQS-20 using TTS techniques. The new AQS-20 mine hunting sensor can obtain swath bathymetry and sediment profile information in a single flight. To refresh the environmental picture, data will be processed, and fused with historical information. The Geophysical Database Variable Grid (GDBV) will be used to store environmental information. MEDAL will be able to subscribe to the dynamic data through SPAWAR's new Tactical Environmental Data Services (TEDServices).

Data Processing

Under SPAWAR PMW 150 sponsorship TTS environmental data collection from the AQS-20 was demonstrated.[2] Data collected in the preliminary work met or exceeded Mine Warfare requirements for bathymetry and doctrinal sediment type. The processing software used in the demonstration is being modified to be more robust, run faster and provide final data products to the dynamic Geophysical Data Base Variable resolution

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(GDBV) data store.[3] The GDBV dynamic database will be hosted locally to store and serve sediment and bathymetry information to the fusion algorithms. It will provide supplemental data to refresh the OMAL approved NAVOCEANO historical databases. Additional dynamic data collected from other sensors like the UQN-4 Fathometer and UUV's could also be stored in the GDBV.

The data processing is naturally divided into two categories based on the data types available from (1) mission data (recorded on the main mission recorder called the Mass Memory Unit (MMU)) and (2) high speed data (recorded on a special High Speed Recorder (HSR)). The reason for two processing streams is to take advantage of all data available from the AQS-20 sonar system when it transitions into operational use. The most valuable environmental information comes from the HSR because it records full dynamic range and resolution from the sonar. This data contains all the information to reconstruct multibeam bathymetry and doctrinal bottom composition. In other operations should the HSR not be available, the MMU data can be used to provide single beam bathymetry for most operational modes of the AQS-20 sonar system.

In the planned demonstrations a HSR will be available, so both types of data processing will be tested. Figure 1 illustrates the data processing flow. Data sources from the AQS-20 will be connected to the workstation computer and accessed directly.

Volume Search Sonar (VSS) data will be extracted from the HSR and processed separately for multibeam bathymetry and sediment properties. A total of 26 beams (13 fore and 13 aft) are processed in the multibeam bathymetry solution and stored in the database as bathymetry soundings. The sediment processing uses the two most downward looking beams and solves for the bottom composition. Bathymetry and bottom composition are stored in the local supplemental database. Data are retrieved from this database on demand by network services to supplement and refresh the historical environmental data stored in local DBDBV and GDBV databases.

The MMU data will be tested using a similar processing flow. In this case, any of the bottom following modes or the volume search operational mode of the AQS-20 can be used to obtain bathymetry. However, only single beam bathymetry is available due to the limitations of the recorded data. The bathymetry soundings are stored in the local supplemental database and provided when required to refresh the historical DBDBV data.

Previous work has determined that the data accuracy will meet or exceed Mine Warfare requirements in most cases.[4] Limitations on the data accuracy appear to be related to the resolution and bias of the pressure sensor used for determining the towbody depth.[5]

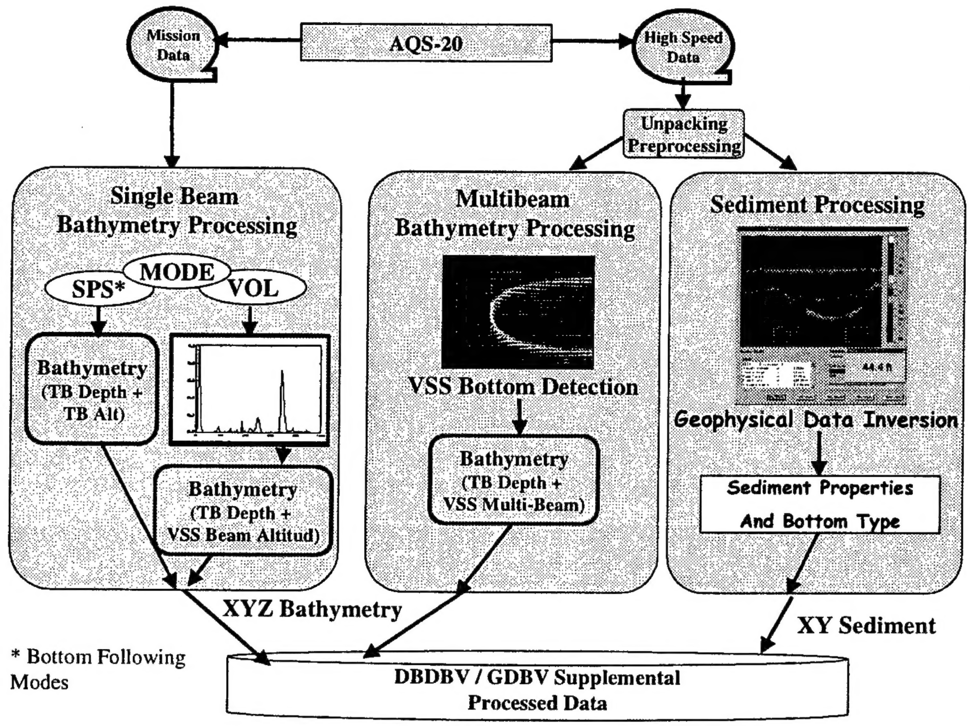

Figure 1.
Data processing components from source to database

Bathymetry Data Fusion

To generate representative environments, dynamic bathymetry and sediment data from multiple sources need to be fused with historical data. Under SPAWAR PMW150's Precision Underwater Mapping Array (PUMA/TEDS) program techniques to merge high-density submarine acquired PUMA bathymetry with historical DBDBV holdings to generate a supplemental layer of bathymetry were developed. The OAML feathering algorithm is the core component of the PUMA/TEDS merging process.[6] These same data merging and feathering techniques are being used to combine MCM dynamic bathymetry with Oceanographic and Atmospheric Master Library (OAML) approved historical DBDBV holdings. In addition, advanced data fusing techniques developed to merge sediment data types may also be applied to bathymetry data.

Sediment Data Fusion

A phased research program is being conducted to develop fusion techniques to extrapolate and merge sediment data. Studies are being conducted to determine the best techniques for fusing dynamic and historical sediment data. An optimal sediment picture needs to be generated from historical sediment polygons, cores, AQS-20 data and other sediment acoustic sources like the UQN-4. These data come from geographically overlapping areas, different sources, and varying resolutions and accuracies. Using in-house research funds, NRL has made progress merging side scan sonar imagery with sediment profile information to generate aerial estimates of surficial sediment types. Under ONR sponsorship Kriging algorithms are being developed to extrapolate TTS data into unsampled or undersampled locations (with confidence estimates). Operators can

then overlay this data with historical data to manually fuse the datasets. In the follow on phase techniques to automatically fuse the historical and TTS data will be developed. This research complements additional ongoing efforts at NAVOCEANO.

Data Distribution

TEDServices will distribute fused data from the dynamic GDBV to onboard and off-board decision aids. During numerous exercises in FY03 and FY04, TEDServices, which is the primary Fleet repository and source of Meteorology and Oceanography (MetOc) data, successfully demonstrated two-way connectivity between data production centers and fleet units. This new technology provides environmental data via subscription and is designed to ensure a common, current environmental view while minimizing bandwidth requirements.[7] MCM dynamic data is stored in GDBV and pushed to TEDServices via a special ingest component that will be integrated into the TEDServices system. Application Programmer Interfaces (API) have been developed to connect TEDServices to the database servers holding the fused data products.

Dynamic sediment and bathymetry data will persist as geo-referenced objects in the local GDBV. TEDServices will be the source for both the OAML DBDB-V and GDBV historical databases, see Figure 2. The OAML GDBV will provide access to the OAML High Frequency Bottom Loss (HFBL), Low Frequency Bottom Loss (LFBL), and Surface Sediment Type (SST) datasets in a single, modern database format. The merge algorithms will request dynamic data from the GDBV and historical data from TEDServices and fuse the results to form an updated grid for a particular region of interest. The fused grid will be passed through TEDServices to MEDAL for near real-time data sharing and enhanced decision support. Additionally, the raw point measurement from the dynamic GDBV may be passed to the MEDAL system for an optional overlay into the existing display.

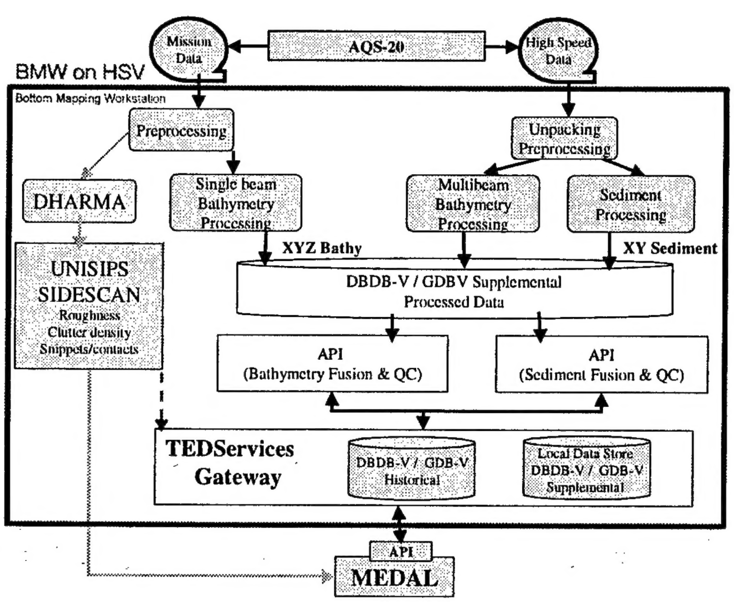

Figure 2.
End-to-End Concept from raw data through processing, storage, dissemination and use

A modified research version of MEDAL will be used with TEDServices to subscribe to the fused data and demonstrate environmental data delivery to the decision aid. Following the Oceanographer of the Navy's Concept of Operations for distributing environmental data, TEDServices provides the Virtual Natural Environment (VNE) with fused dynamic and historical information that Centers of Expertise or Ships afloat using MEDAL can ingest.

Demonstrations

Three demonstrations of the end-to-end capability are planned for FY05. The first demo will be a representative simulation showing connectivity and functionality using previously collected raw AQS-20 EDM data with other overlapping historical data sets south of Panama City. The data will be processed and fused in the lab, and placed in DBDBV and GDBV on a server. A TEDServices gateway will connect the data and MEDAL.

The second demo will use land based MH-53 flights with the AQS-20 EDM flown out of Panama City with the databases and servers set up in hangar and laboratory areas on site. Procedures and processing times will be established. The final demo will be conducted at sea demonstrating end-to-end delivery of TTS data from sensor to tactical decision aid. This demonstration will use the HSV-X in an MCM command ship role.

Transition

After successful completion of the demonstrations, environmental data extraction and merging software will be incorporated into the Bottom Mapping Workstation (BMW). The BMW is currently maintained at the Naval Oceanographic Office and is used by Bottom Mapping Teams in theatre to provide environmental information for Mine Warfare Operations.

Summary/conclusion

Accurate seafloor environmental information is crucial to the success of mine hunting operations. Historical environmental data must be supplemented with near real-time information to verify data quality, supplement low-resolution information, and in some cases replace inaccurate or perishable data.

With fleet endorsements from OPNAV and COMINEWARCOM, NRL is developing end-to-end techniques to fuse near real-time Through-The-Sensor data with historical information and provide it to MEDAL. AQS-20 environmental data extraction and processing algorithms have been developed and demonstrated. Techniques to fuse dynamic bathymetry and sediment data with historical information are being developed. The dynamic GDBV has been developed for archiving MCM seafloor information in a manner that supports "on-the-fly" data fusion techniques. TEDServices has demonstrated its ability to serve environmental data in numerous exercises.

Future efforts include demonstrations of the end-to-end connectivity. TEDServices will be expanded to provide the fused MCM environmental data to MEDAL. The processing software, fusion algorithms, and dynamic GDBV will be

integrated into NAVOCEANO's Bottom Mapping Workstation. The impact to the mine warfare community will be improved real-time data receipt and reduced MCM timelines.

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